The Art and Science of Source-Receptor Modeling

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Presentation Outline

1 Description & history of source-receptor modeling

2 Overview of state-of-the-art ozone modeling

3 Issues for $PM_{2.5}$/regional haze modeling

4 DOE-TVA study of fossil utility boiler impacts on $PM_{2.5}$ levels

Electric Utility Air Issues

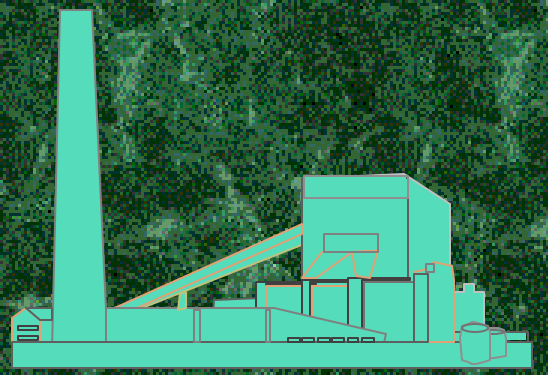
Examined with Source-Receptor Modeling:

- Ozone attainment
- $PM_{2.5}$ attainment
- Regional haze
- Sulfur & nitrogen deposition

Not Examined with Source-Receptor Modeling:

- Greenhouse gas reduction (CO_2)

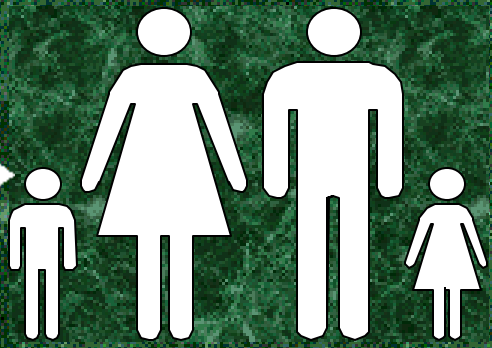
What Is Source-Receptor Modeling?



Regulation

SRM links source emissions with downwind impacts using knowledge of meteorology & atmospheric chemistry

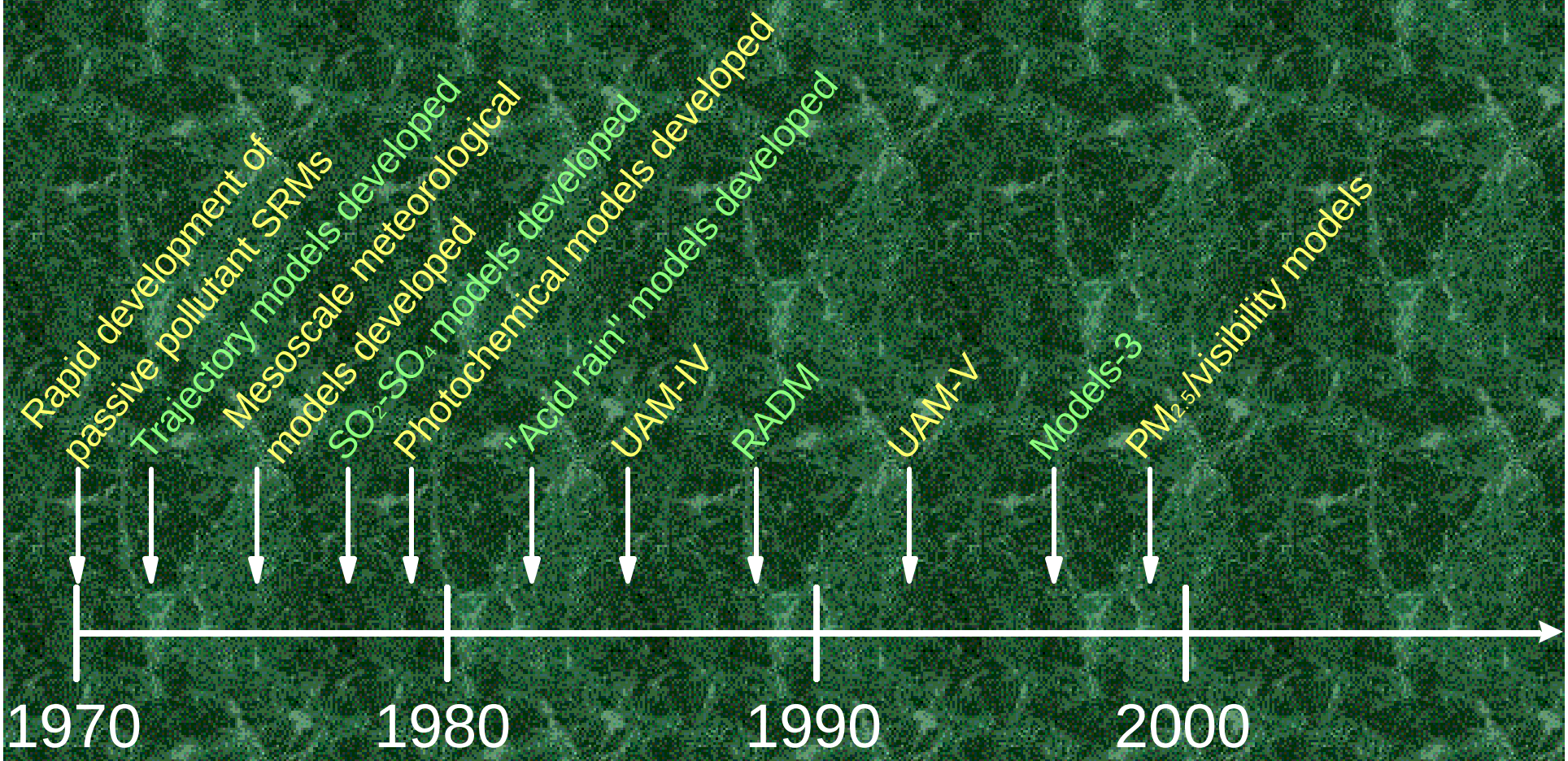
Research



Definitions: source & receptor

- A source is any point or area from which pollutants are emitted (point, area, line)
- A receptor is any point at which a pollutant impact is to be computed (receptors can be on ground or elevated)

Evolution of Source-Receptor Modeling

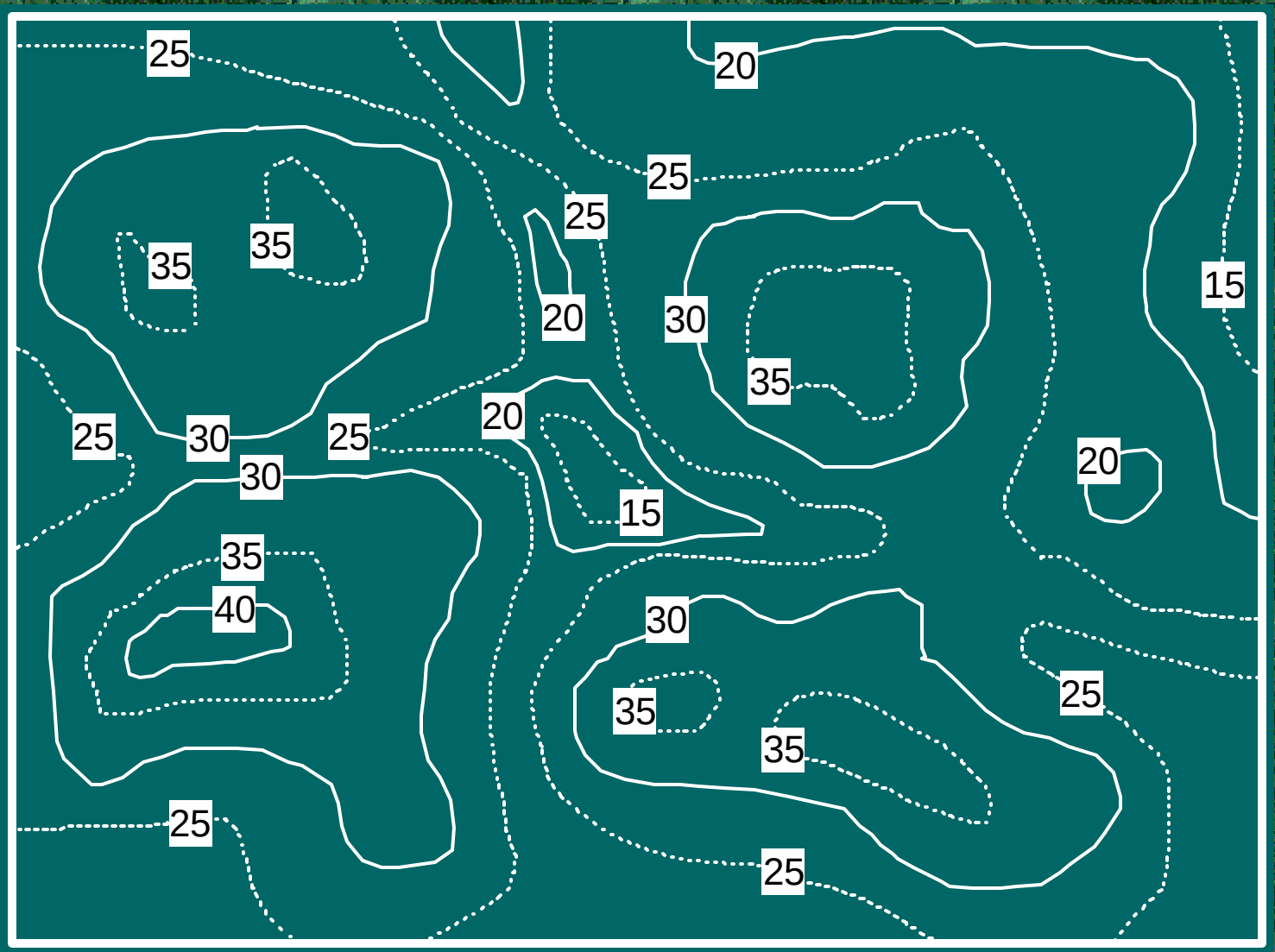


Definition: passive pollutant

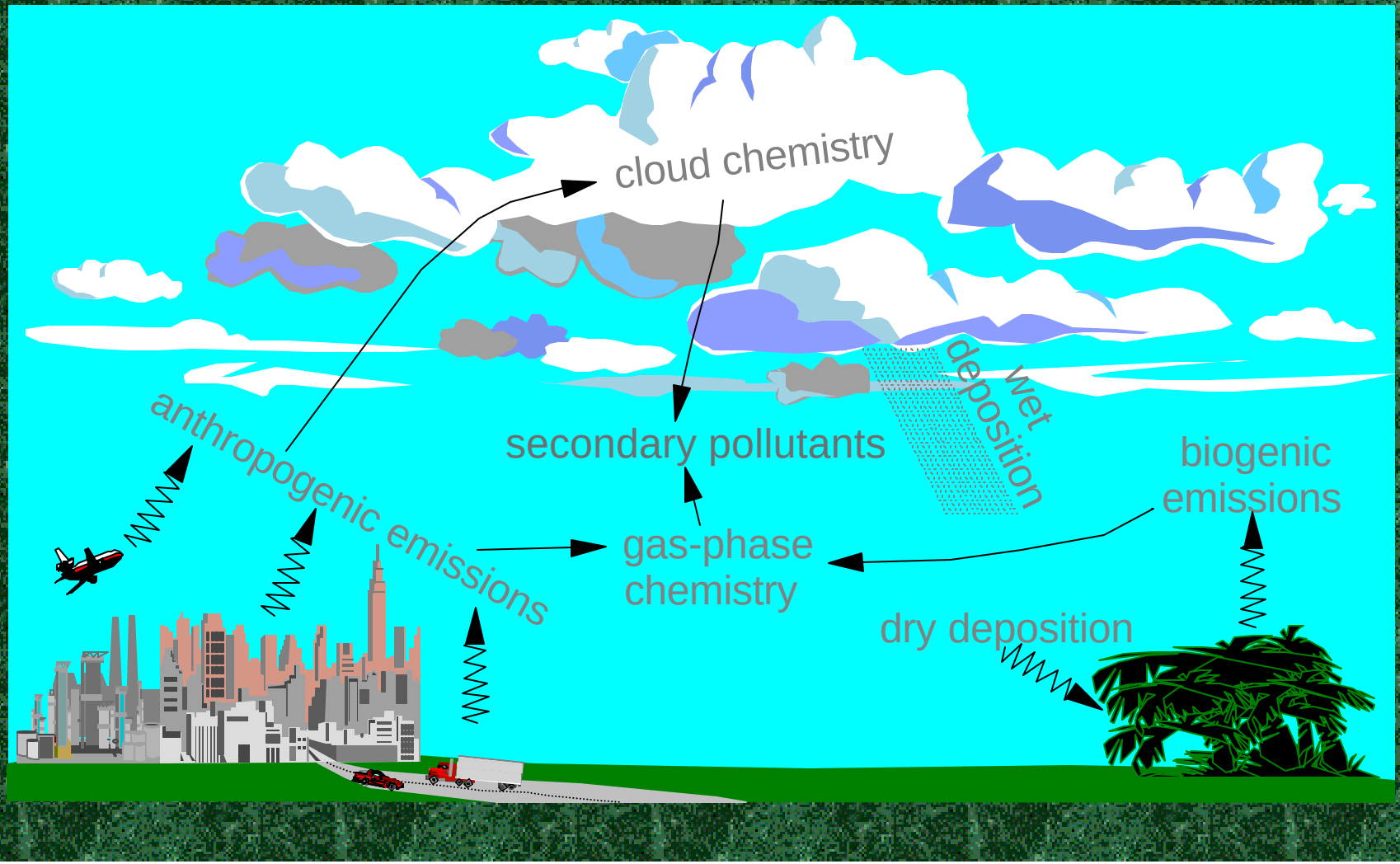
- A passive pollutant is any material that does not react with its environment (i.e., transport and diffusion only)

- Pollutants treated as “passive” in early models:
  - sulfur dioxide
  - carbon monoxide
  - nitrogen oxides
  - particles (TSP & lead)

Passive Pollutant SRM



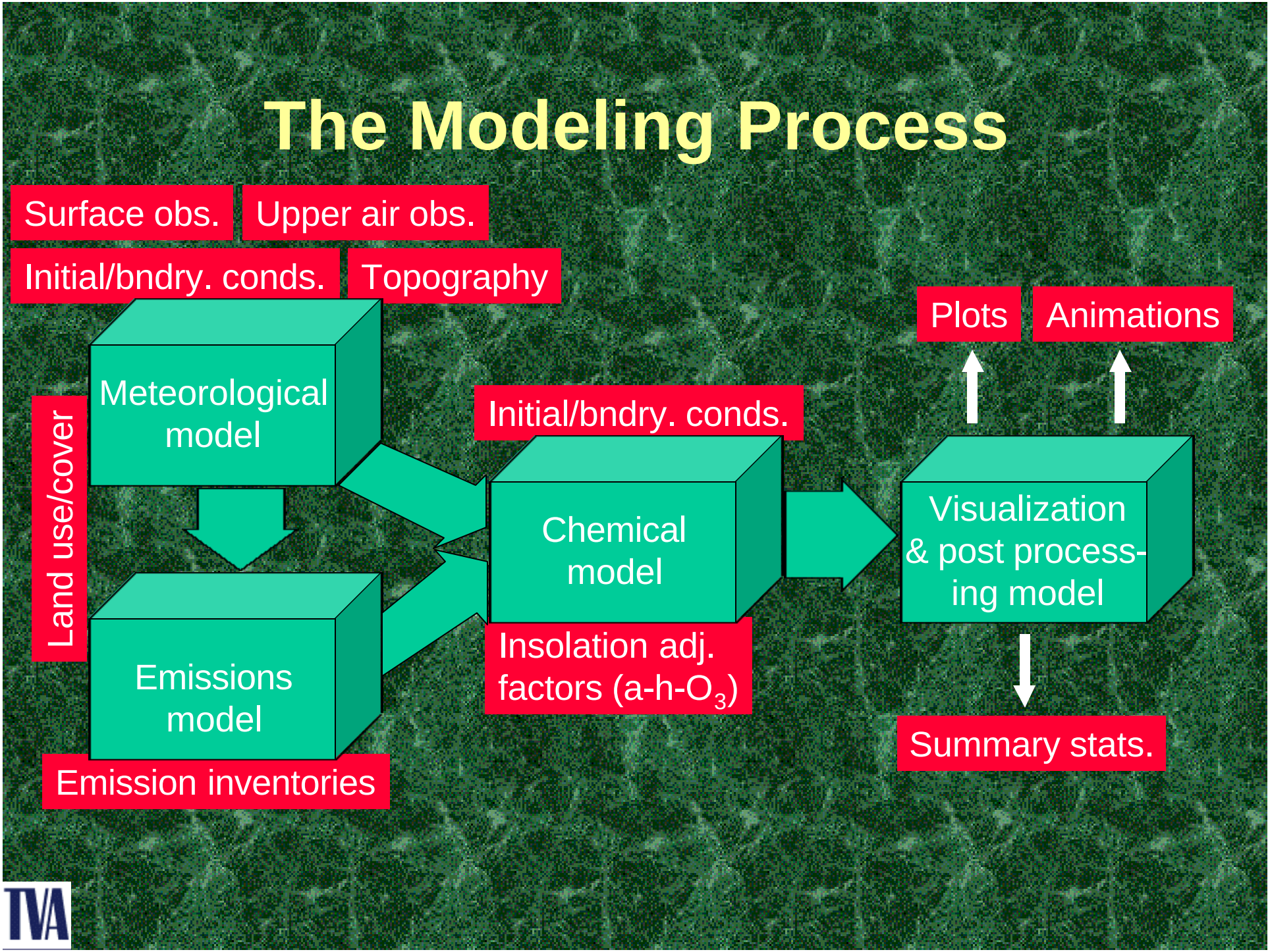
Lifecycle of Atmospheric Pollutants



Secondary Pollutants: The Case for Non-Passive Pollutant Modeling

- Ozone
- Sulfate (particles or “acid deposition”)
- Nitrate (particles or “acid deposition”)
- $PM_{2.5}$ (including organic aerosols)

The Modeling Process



Computer Resource Usage

	UAM-V (O_3 only)	URM (O_3 & particles)
Output Disk Storage (Mb per 10^5 nodes per day)	38	90
CPU time (cpu days per 10^5 nodes per day)	0.07	0.10

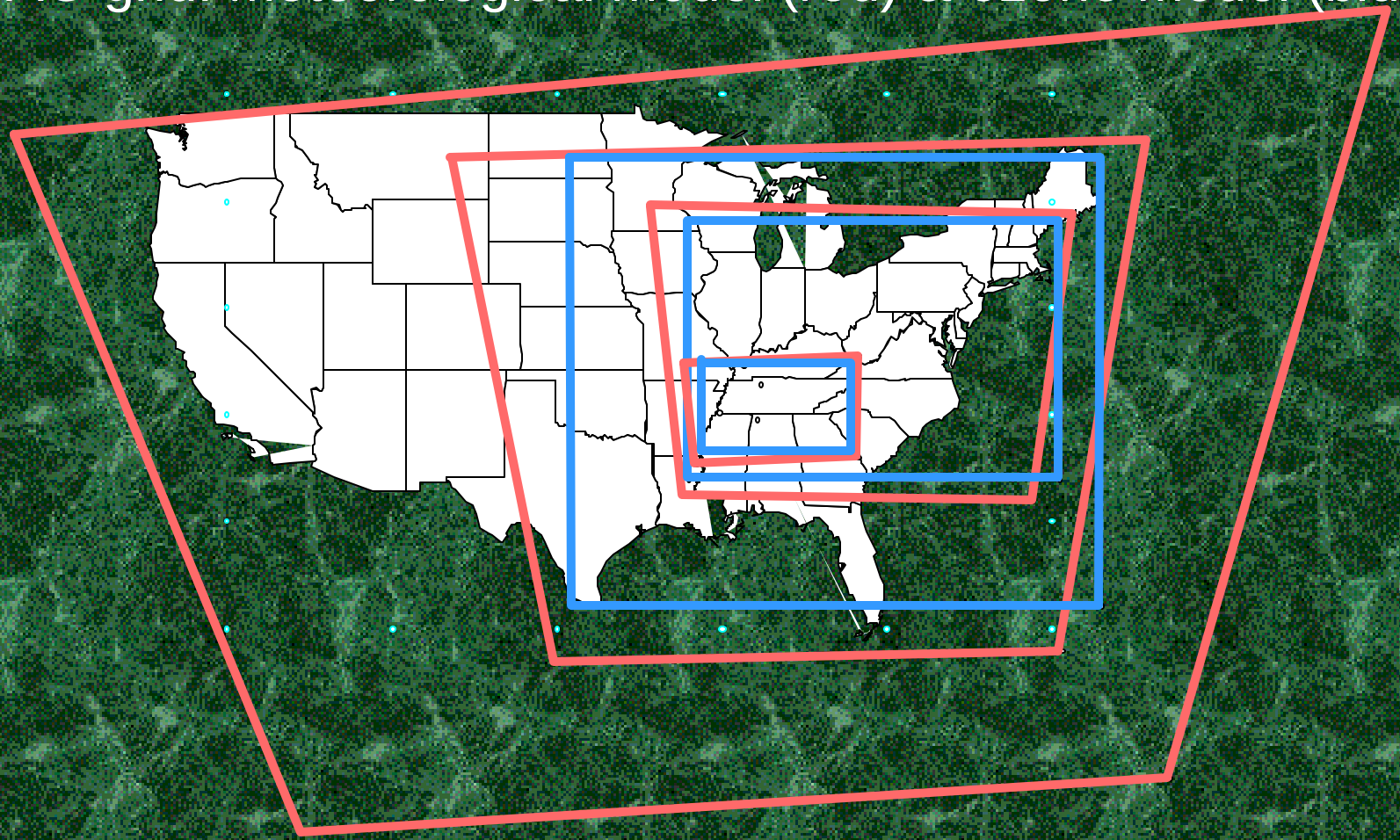
Note: cpu times for models runs on Alpha 4100 600 MHz processor

Emerging $PM_{2.5}$ Models

- Models-3 (public domain)
- URM-SAMI (developed for SAMI)
- CAMX (public domain)
- UAM-AERO (licensed)

Typical Advanced Modeling Grid System

OTAG grid: meteorological model (red) & ozone model (blue)

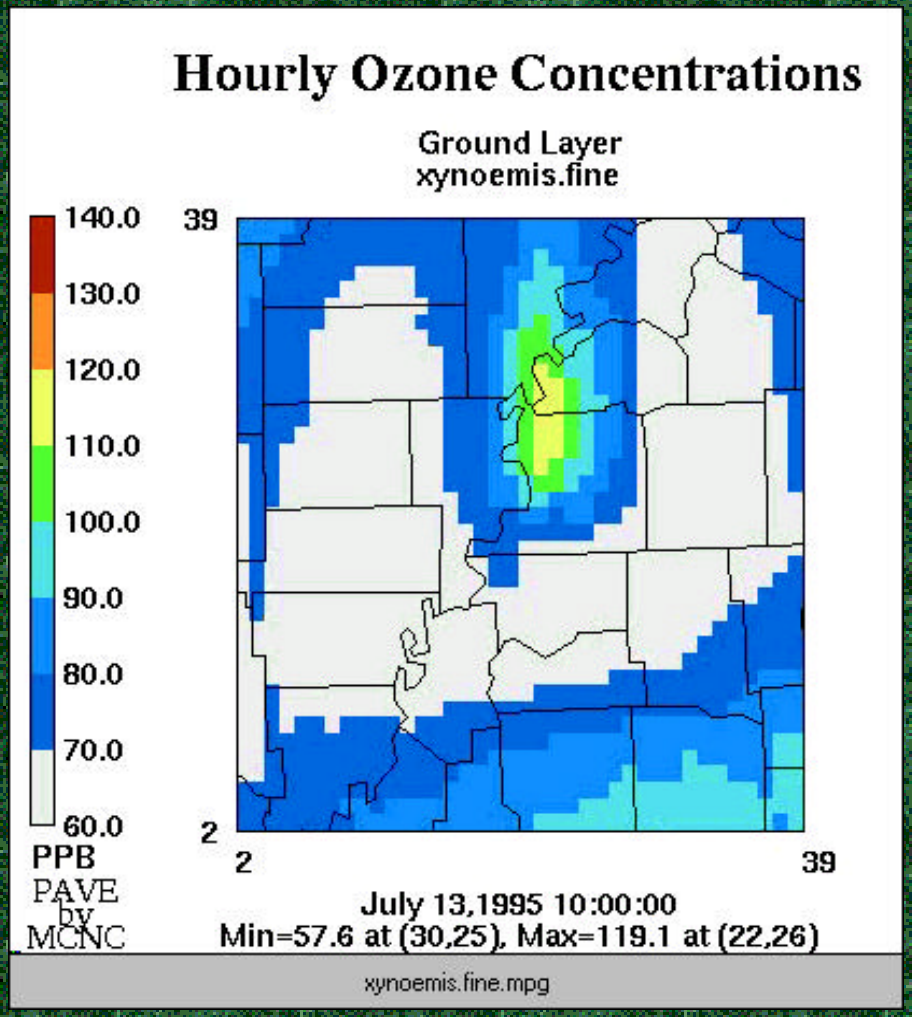


The Modeler as Artist

- Defines grid boundaries & spatial resolutions representing region of interest
- Selects meteorological parameterizations approximating important processes (e.g., diffusion, convective mixing, soil moisture)
- Selects boundary & initial conditions
- Determines which sources to treat with plume-in-grid option
- Selects output visualization methods to best illustrate results of interest

Typical Ozone Model Output Memphis: 10-14 July 1995

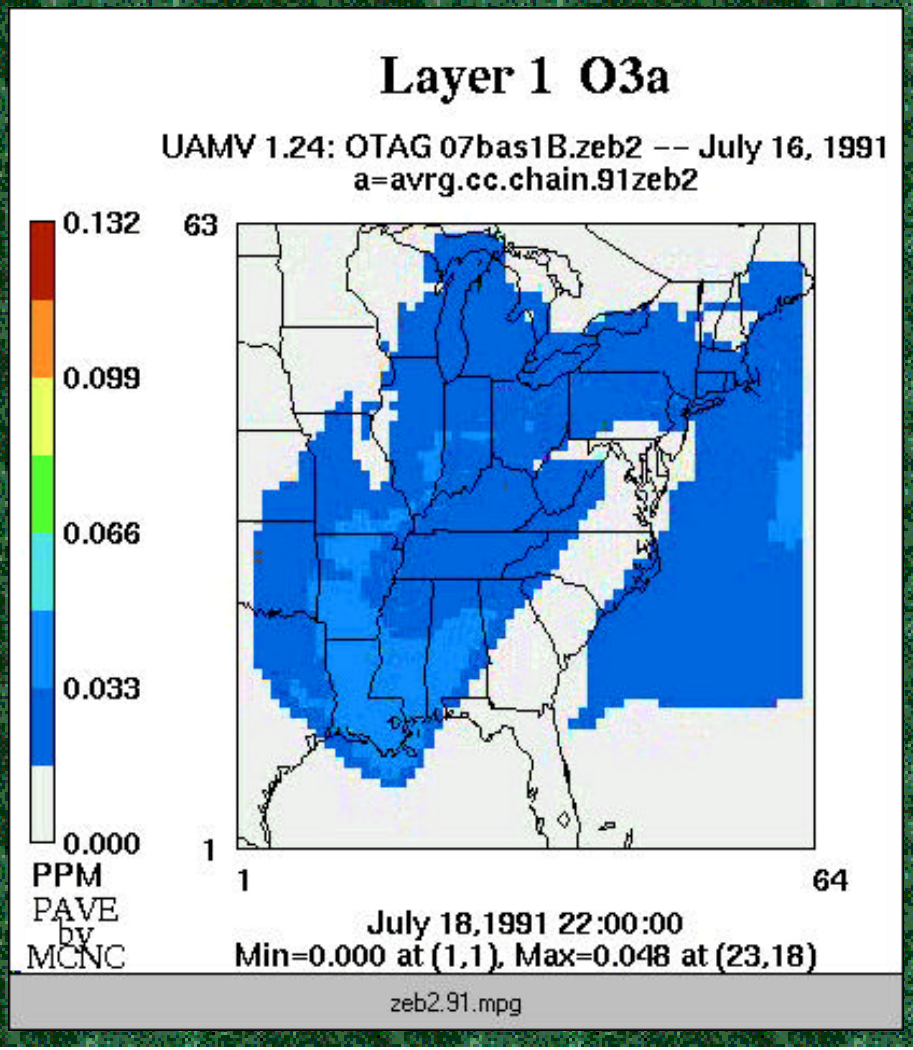
Model: UAM-V
Ground-level O_3
Grid: 200x200 km
Resolution: 5 km



Treatment:
actual emissions

Illustrating Large-scale Ozone Transport

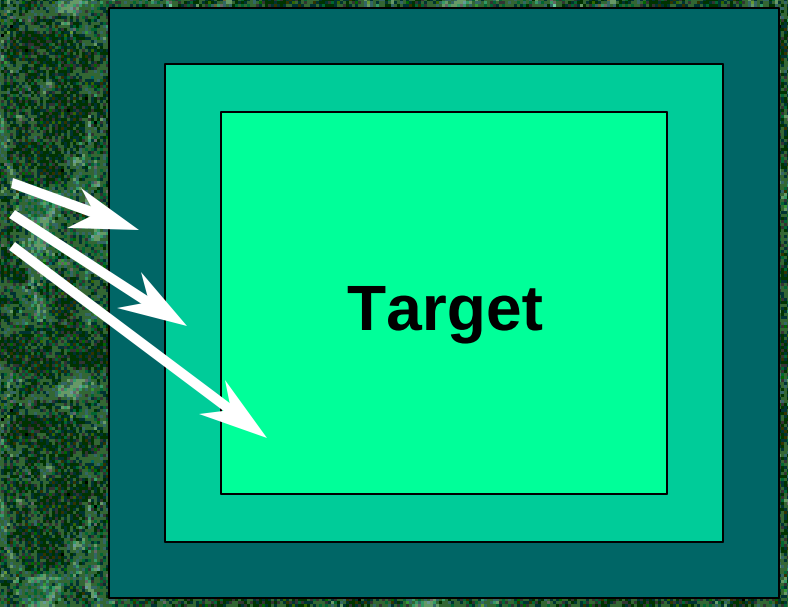
Model: UAM-V
Ground-level O_3
Grid: 2304x2268 km
Resolution: 36 km



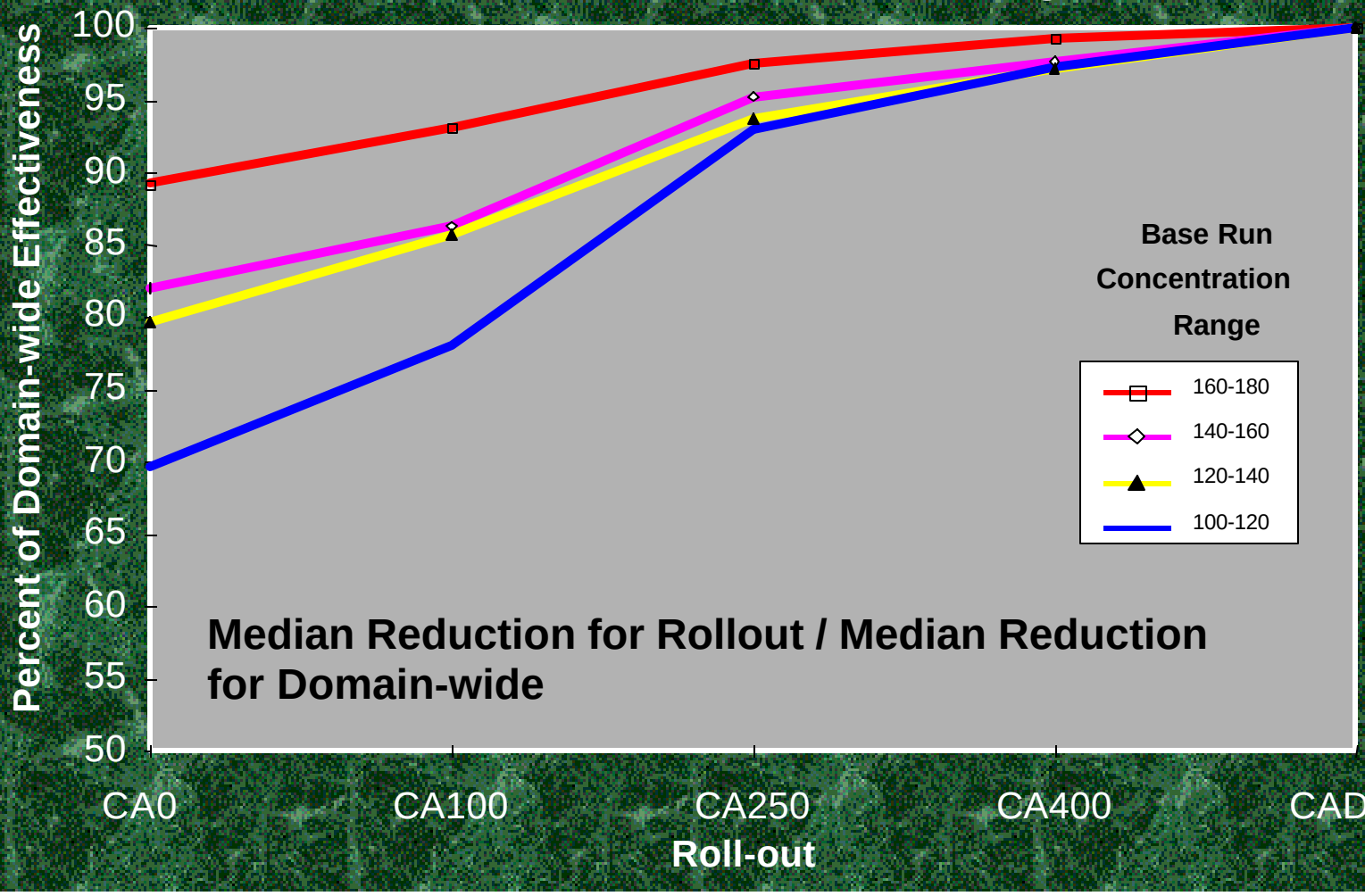
Treatment:
actual emissions through 1400 on 16 July 1991, then biogenics only for 4 days

Modeling the NO_x Controls "Roll-out" Concept

Alternate NO_x control regions



Illustrating NO_x Control Effectiveness ("Roll-out" Strategy)



Beyond Ozone: $PM_{2.5}$/Visibility Modeling

Requirements:

- Cloud & precipitation simulations
- Treatment of sulfur compounds: SO_2, SO_3, H_2SO_4, $(NH_4)_2SO_4$, bisulfite, etc.
- Ammonia & ammonium chemistry
- Elemental carbon, crustal minerals, nitrate aerosols
- Organic aerosols
- Aqueous-phase (cloud & rain water) reactions involving all aerosols
- Physics of light scattering & absorption

TVA

Differences Among $PM_{2.5}$ Models

- Varying photochemistry
- Different aerosol thermodynamics
- Differences in methods used to represent aerosol size distributions
- Different treatments of organic aerosols

Options for Modeling $PM_{2.5}$

- **Models-3**

Positives

EPA model
Non-proprietary
Wide user community (expected)
Peer reviewed for EPA

Negatives

Untested
Limited availability of input data sets
Computer restrictions
Simplified aerosol physics

- **URM**

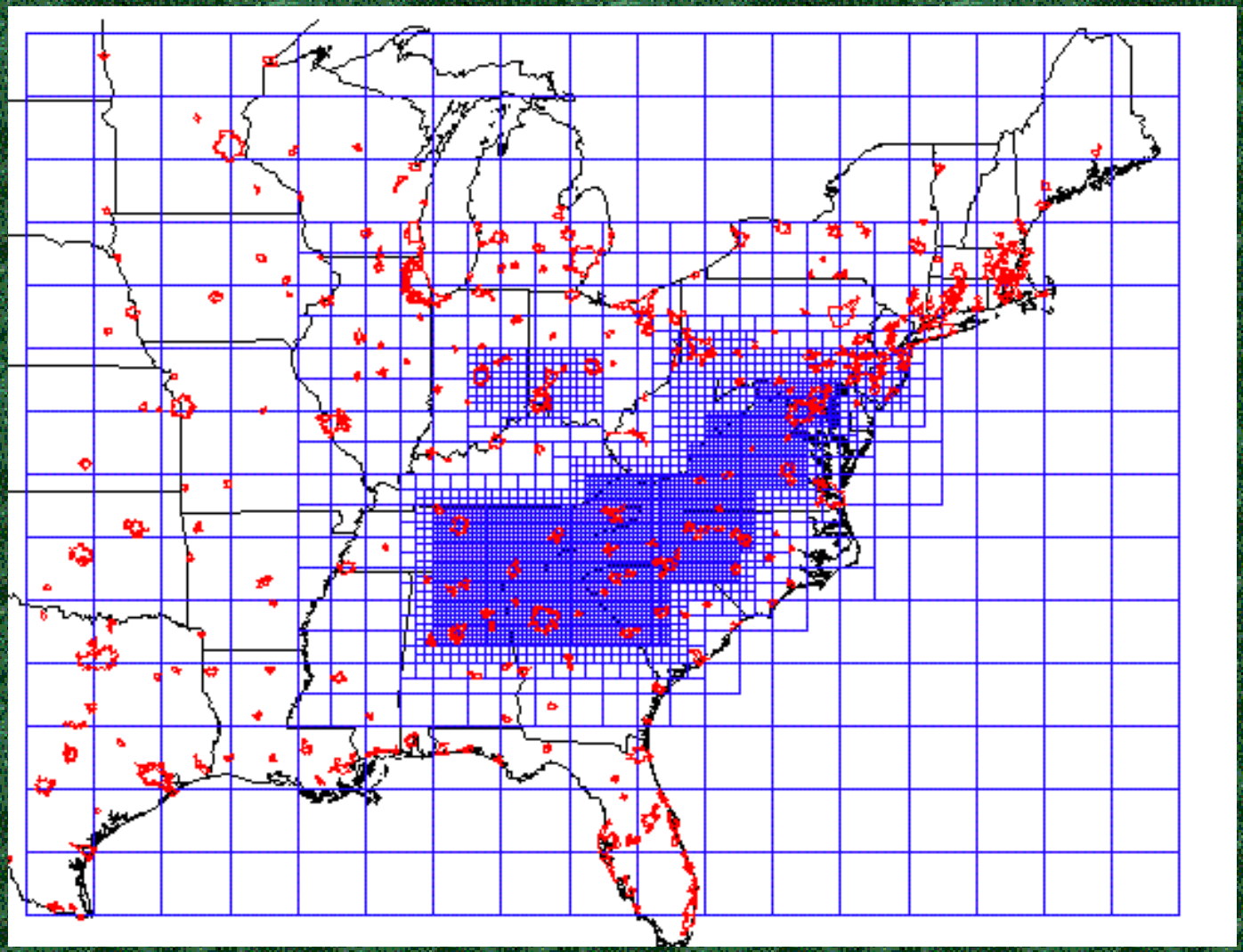
Positives

Currently being applied in public forum (SAMI)
Peer reviewed for SAMI
Sophisticated aerosol physics
Input data sets available
Sensitivity analysis capability

Negatives

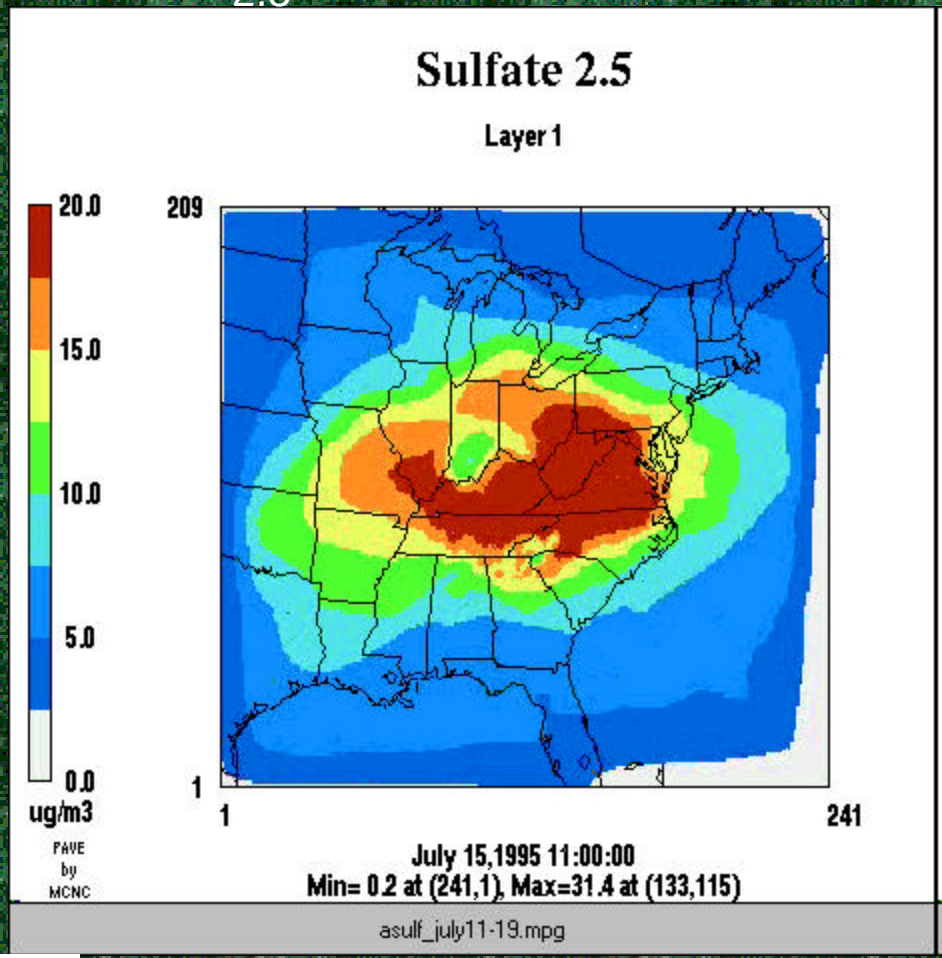
Relatively untested
Restricted user community
Developmental problems

SAMI URM Domain

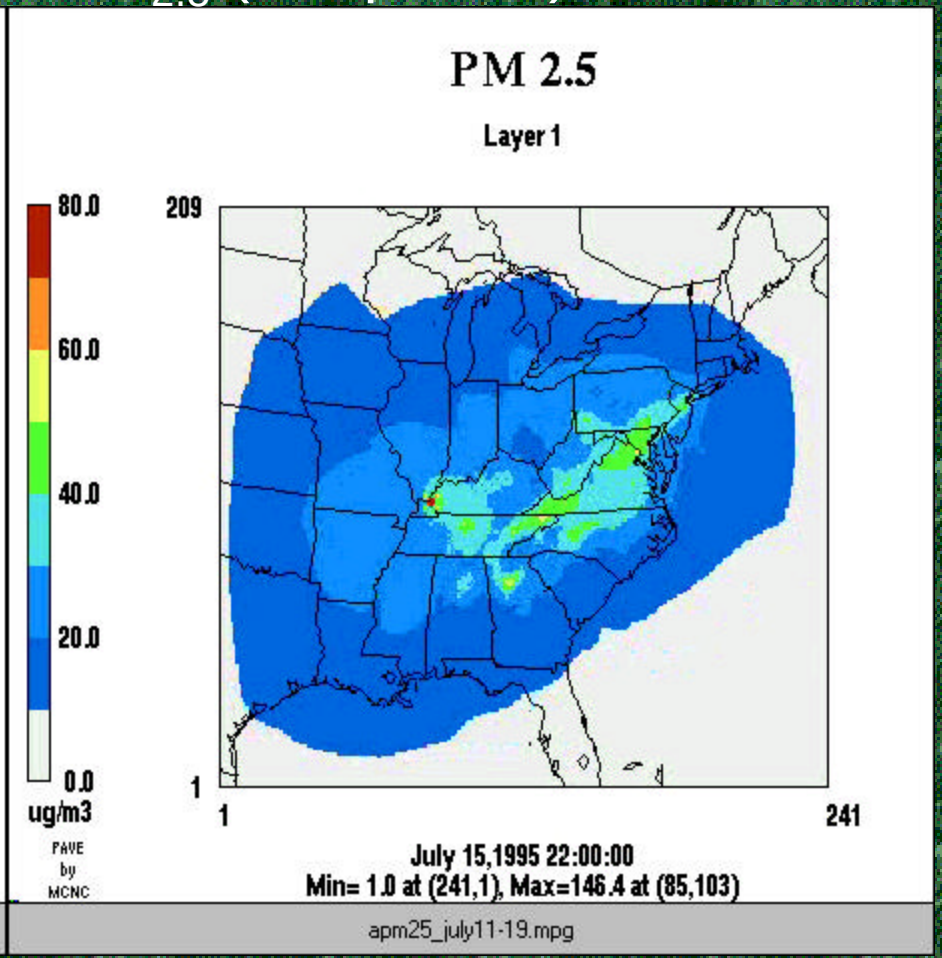


Some URM Results

$PM_{2.5}$ Sulfate - Surface



$PM_{2.5}$ (all species) - Surface



11-19 July 1995

What can modeling tell us about $PM_{2.5}$?

- How do $PM_{2.5}$ levels change with changes in SO_2 emissions? NO_x emissions?
- Are $PM_{2.5}$ responses to emissions changes geographically homogeneous?
- Will proposed NO_x emissions reductions for ozone benefit $PM_{2.5}$ appreciably?
- What sources need to be controlled, and by how much, to comply with $PM_{2.5}$ NAAQS?
- What is the biogenic contribution to $PM_{2.5}$?

$PM_{2.5}$ Modeling Strategy for DOE-TVA Study

"Plan A"

Apply URM-SAMI using existing SAMI emissions, meteorological & other input files